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Sethuraman et al.

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(54) **STATIC FOAM GENERATING APPARATUS AND METHOD**

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(52) **U.S. Cl.** **366/101**; 106/677; 261/DIG. 26; 366/340; 516/10; 516/14

(58) **Field of Search** 516/10, 14; 366/101, 366/340; 261/DIG. 26; 106/677

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(57) **ABSTRACT**

A static foam generating apparatus including a pipe having an inner diameter, an axis, an input end, and an output end is disclosed. A plurality of perforated discs are disposed in the pipe, the discs positioned parallel to each other and perpendicular to the pipe axis. A plurality of spacer rings are disposed within the pipe, a spacer ring separating each perforated disc from each adjacent perforated disc. Additionally, a method for generating foam including the steps of providing a static foam generating apparatus including a pipe having an inner diameter, an axis, an input end, and an output end, supplying feed water to the pipe, supplying surfactant to the pipe, and supplying air to the pipe is disclosed.

5 Claims, 2 Drawing Sheets

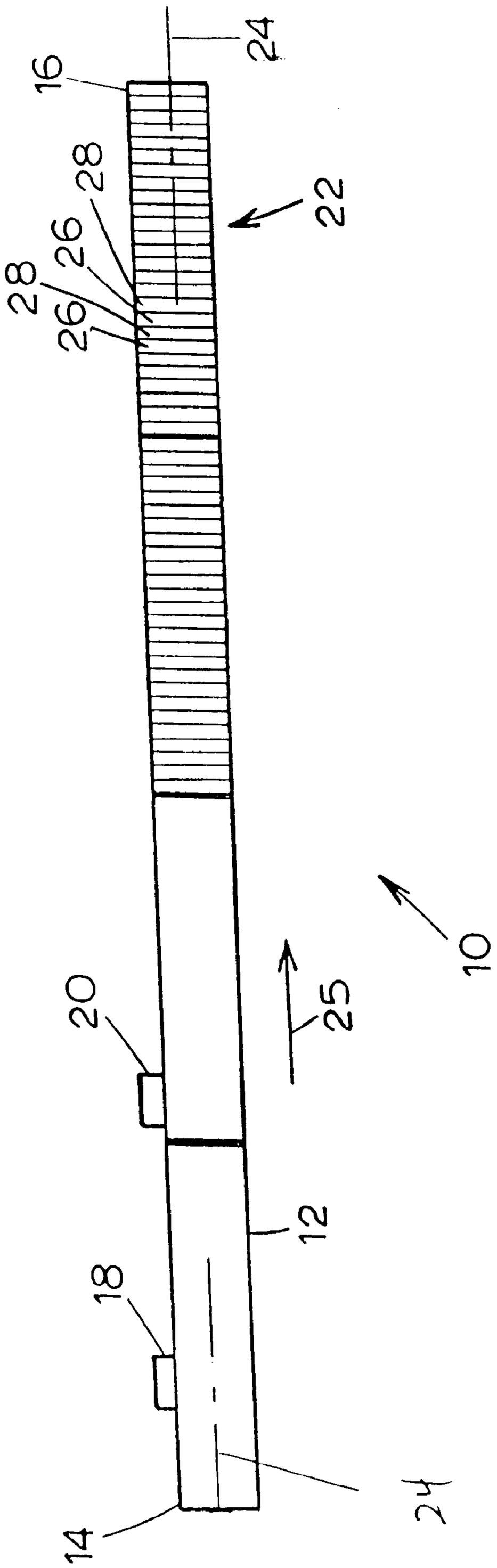

Fig. 1

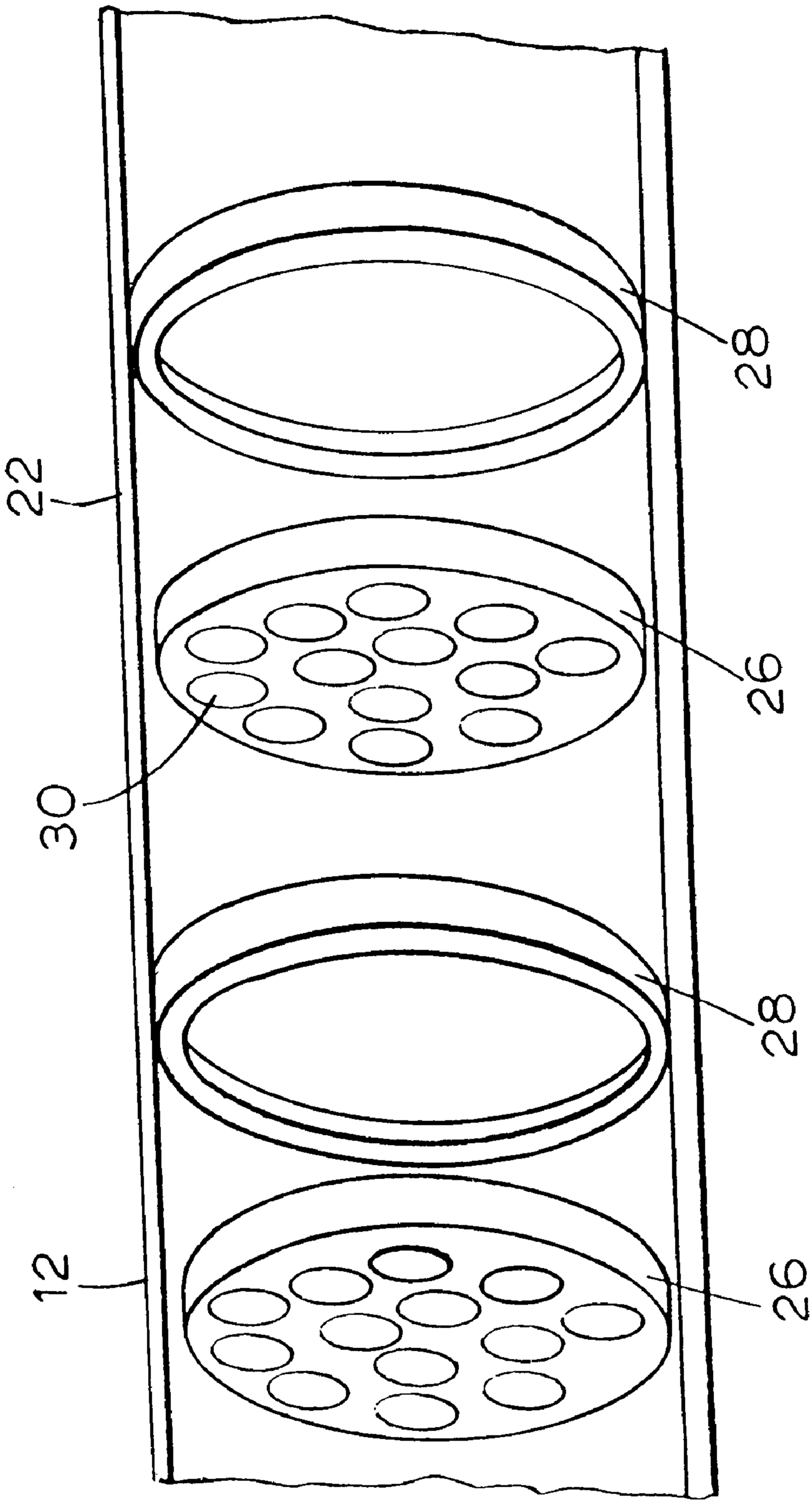

Fig. 2

STATIC FOAM GENERATING APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to methods and apparatus for generating foam, and in particular to methods and apparatus for generating foam for use in producing gypsum wallboards.

2. Description of Related Technology

Gypsum wallboard is typically produced by depositing an aqueous slurry of calcined gypsum between two continuously-supplied moving sheets of cover paper. The calcined gypsum is then allowed to set, forming a core between the two cover sheets, and the continuously-produced board may then be cut into panels of any desired length. As described for example in Johnson, U.S. Pat. No. 4,455,271, the disclosure of which is incorporated herein by reference, a gypsum board with reduced density and good board strength is typically manufactured by generating an aqueous foam in a foam generating apparatus and adding the foam to the gypsum slurry that forms the gypsum board core.

Foams for use in producing gypsum boards are typically generated in a mechanical foam generating apparatus, such as that described in U.S. Pat. No. 4,057,443, the disclosure of which is incorporated herein by reference. A foam generating apparatus typically includes an electric motor used to drive an agitator, which blends a surfactant and water to generate the foam. Consequently, a foam generating apparatus is typically expensive to operate and maintain, and includes mechanical components that are subject to wear and failure.

Static foam generating equipment, such as a cylindrical static mixer described in Johnson, U.S. Pat. No. 4,455,271 has also been used to generate foam for use in a gypsum wallboard core. The static mixer described in the Johnson patent is a six-foot-long tube packed with randomly arranged ceramic saddles in a five-foot portion of the tube and ceramic rings packed in a one-foot portion of the tube. There is a need for an improved apparatus for generating foam that is inexpensive and reliable to operate, and that consistently produces a uniform, high quality foam, which may be used to produce high quality gypsum wallboard.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, a static foam generating apparatus includes a pipe having an inner diameter, an axis, an input end, and an output end. A plurality of perforated discs are disposed in the pipe, the discs positioned parallel to each other and perpendicular to the pipe axis. A plurality of spacer rings are disposed within the pipe, a spacer ring separating each perforated disc from each adjacent perforated disc.

According to another aspect of the present invention, a method for generating foam includes a step of providing a static foam generating apparatus including a pipe having an inner diameter, an axis, an input end, and an output end. The apparatus also includes a plurality of perforated discs disposed in the pipe, the discs positioned parallel to each other and perpendicular to the pipe axis. A plurality of spacer rings are disposed within the pipe, a spacer ring separating each perforated disc from each adjacent perforated disc. The method also includes the steps supplying feed water to the pipe, supplying surfactant to the pipe, and supplying air to the pipe.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a static foam generating apparatus of the present invention;

FIG. **2** is an exploded view of a portion of the foam generating apparatus of FIG. **1**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

As shown in FIG. **1**, a static foam generating apparatus **10** includes a pipe **12** having an input end **14** at which feed water is supplied and an output end **16**. The output end **16** may be connected to a gypsum pin mixer apparatus (not shown). The pipe **12** includes a surfactant inlet **18**, an air inlet **20**, and a mixing region **22**, a representative portion of which is shown in more detail in FIG. **2**. The pipe **12** has an axis **24**, and an inner diameter that typically is about 1 inch to about 3 inches (about 2.5 cm to about 7.6 cm). Pipe **12** can be, for example, a 1.95-inch-inner-diameter (about 5.0-cm-inner-diameter) schedule-80 PVC (polyvinyl chloride) pipe. Water, surfactant, and air flow through the apparatus 10 in the direction indicated by an arrow **25** in FIG. **1**.

The mixing region **22** of the pipe **12** includes a plurality of perforated disks **26** separated by spacer rings **28**, as shown in FIGS. **1** and **2**. The perforated disks **26** and spacers **28** are sized to fit tightly inside of the pipe **12**, preferably having an outer diameter that is slightly less than the inner diameter of the pipe **12**. The entire mixing region **22** preferably is packed with disks **26** and spacers **28**, packed closely together in an alternating arrangement, oriented parallel to each other and perpendicular to the axis **24** of the pipe **12**. Preferably, each adjacent disk **26** and spacer **28** are in contact with each other. The mixing region typically has a length from about 2 feet to about 10 feet (about 0.61 m to about 3.0 m), and preferably has a length of about 5 feet (about 1.5 m). Preferably, each perforated disk **26** has a thickness of about 0.10" to about 0.30" (about 0.25 cm to about 0.76 cm), and each spacer **28** has a thickness of about ¼" to about 1 ¼" (about 0.64 cm to about 3.2 cm). Each perforated disk **26** preferably has a plurality of perforations **30**, each having a diameter of about ⅛" to about ¾" (about 0.32 cm to about 1.9 cm). Preferably, the perforations **30** are uniformly spaced on the discs **26**, and adjacent discs **26** are oriented so that the perforations **30** in each disc **26** are generally staggered in position with respect to the perforations **30** in adjacent discs **26**. In one embodiment, the pipe **12** has an inner diameter of about 1.95" (about 5.0 cm), the perforated disks **26** have a thickness of about 0.1875" (about 0.48 cm) and an outer diameter of about 1.91" (about 4.9 cm), the perforations have a diameter of about ½" (about 1.3 cm), each disk **26** includes about 8 perforations, and the spacers **28** have a thickness of about ¾" (about 1.9 cm) and an outer diameter of about 1.9" (about 4.8 cm). The perforated disks **26** and spacers **28** may be made from any rigid material, such as PVC. Although the pipe and perforations shown in FIGS. **1** and **2** have circular cross-sections, it is understood that the cross-sections can have other shapes, such as an oval cross section.

According to a preferred method of producing foam for use in a gypsum pin mixer, feed water is supplied to the input end **14** of the pipe **12** at a rate of about 300 lbs water per thousand square feet of gypsum board (300 lbs/MSF) to about 400 lbs/MSF (about 1465 kg/1000 m^2 to about 1950 kg/1000 m^2). For a gypsum board line running at a rate of about 162 ft/min (about 82.3 cm/sec), the flow rate of water is typically between about 20 gal/min to about 40 gal/min (about 75.7 L/min to about 151 L/min). Surfactant is sup-

plied to the surfactant inlet **18**, downstream of the input end **14**, typically at a rate of about 0.4 lbs/MSF to about 1.0 lbs/MSF (about 2.0 kg/1000 m^2 to about 4.9 kg/1000 m^2). The surfactant can be, for example, a C_8–C_{12} anionic or nonionic surfactant, or an ammonium salt of an ethoxylated alcohol sulfate. As known to those skilled in the art, such surfactants typically include about 40% to about 50% by weight active ingredients, with the balance including solvents (e.g., isopropyl alcohol) and other ingredients. Air is supplied to the apparatus **10** at the air inlet **20**, downstream of the surfactant inlet **18**, typically at a rate of about 10 cubic feet per minute (CFM) to about 16 CFM (about 4.7 L/sec to about 7.5 L/sec).

Foam produced by the apparatus **10** is discharged from the apparatus **10** at the output end **16**, and the foam can be inserted into or combined with a gypsum slurry in a gypsum pin mixer by apparatus and methods known to those skilled in the art. As shown in Examples 1 and 2 below, the gypsum boards produced with foam generated by the apparatus **10** have board strengths similar to, or greater than, those produced with prior foam-generating equipment typically used with gypsum pin mixers. The apparatus **10** is less expensive to operate and maintain than a typical prior mechanical foam generating apparatus, because the apparatus **10** does not include any motor-driven agitator.

EXAMPLE 1

Foam was generated using a static foam generating apparatus and inserted into a pin mixer for use in gypsum boards including the following ingredients, under the following conditions:

board line speed: 162 ft/min (82.3 cm/sec)

board weight: 1750 lbs/MSF (8544 kg/1000 m^2)

stucco: 900 lbs/MSF (4394 kg/1000 m^2)

foam water: 380 lbs/MSF (29.6 gal/min) (1855 kg/l000 m^2) (112 L/min)

surfactant: 0.81 lbs/MSF (4.0 kg/1000 m^2)

surfactant type: Surfactant TF Foamer (ammonium salt of ethoxylated alcohol sulfate), supplied by Thatcher Company, Salt Lake City, Utah.

pulp water: 227 lbs/MSF (1108 kg/1000 m^2) (supplied to gypsum pin mixer)

foam air: approx. 12.8 CFM (6.0 L/sec)

pipe used: PVC schedule 80

mixing region length: 5 ft (1.5 m)

perforated disks: 0.1875" thick (0.476 cm)

perforations: ½" diameter (1.27 cm)

spacers: ¾" wide (1.9 cm) PVC

Gypsum boards having a thickness of about ½" and a width of about 4 ft were produced, and two randomly-selected boards were tested for strength by the Nail Pull Resistance Test Method B (ASTM Method C 473-99, section 13) and for compressive strength using an Instron 4486 instrument (supplied by the Instron Company of Canton, Mass.). Each tested board was tested at several locations on the board. The following results were obtained:

	Nail Pull Test			
	Board No. 1		Board No. 2	
Test No.	(lbs F)	(N)	(lbs F)	(N)
1	65.2	290	74.62	332
2	65.35	291	61.14	272
3	67.77	301	74.1	330
4	58.3	259	63.14	281
5	65.42	291	66.43	296
6	67.69	301	70.95	316
7	74.6	332	65.22	290
8	71.49	318	69.67	310
9	72.01	320	68.29	304
10	68.75	306	N/A	
Average (of 6 highest values)	70 (±3)	311 (±13)	70 (±3)	311 (±13)

	Compressive Strength			
	Board No. 1		Board No. 2	
Test No.	(psi)	(kg/cm^2)	(psi)	(kg/cm^2)
1	335.6	23.6	381	26.8
2	398.2	28.0	323	22.7
3	337.7	23.7	329.9	23.2
4	339.3	23.9	344.6	24.2
5	350.1	24.6	350.6	24.7
6	351.0	24.7	351.0	24.7
7	350.1	24.6	362.4	25.5
8	354.6	24.9	366.3	25.8
9	356.1	25.0	381.0	26.8
Average (of 6 highest values)	360 (±14)	25.3 (±1.0)	359 (±14)	25.2 (±1.0)

EXAMPLE 2

Foam was generated using a prior mechanical foam generating apparatus, which generated foam by pumping air, water, and surfactant through two gear pumps in series, the pumps driven by a 20 H.P. electric motor, under conditions otherwise similar to those for Example 1 above. Gypsum boards having a thickness of about ½" and a width of about 4 ft were produced, and a randomly-selected board was tested for strength by the Nail Pull Resistance Test Method B (ASTM Method C 473-99, section 13) and for compressive strength using an Instron 4486 instrument (supplied by the Instron Company of Canton, Mass.). The following results were obtained:

	Nail Pull Test	
	Test Results	
Test No.	(lbs F)	(N)
1	60	267
2	61	271
3	66	294
4	63	280
5	57	254
6	66.1	294
7	67	298

-continued

Nail Pull Test

Test No.	Test Results (lbs F)	(N)
8	69.12	307
9	67	298
10	69.14	308
Average (of 6 highest values)	67 (±2)	298 (±9)

Compressive Strength

Test No.	Test Results (psi)	(kg/cm^2)
1	285.4	20.1
2	286.3	20.1
3	337.6	23.7
4	316.1	22.2
5	286.9	20.2
6	295.1	20.7
7	296.3	20.8
8	305.4	21.5
9	307.1	21.6
Average (of highest values)	310 (±16)	21.8 (±1.1)

As shown by the test results reported in Example 1 and Example 2, gypsum boards produced with foam generated by the static foam generating apparatus have board strengths that are similar to, or greater than, the strengths of boards produced under similar conditions except including foam produced with prior foam-generating equipment typically used with pin mixers. The foregoing detailed description is given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications within the scope of the invention will be apparent to those skilled in the art.

What is claimed is:

1. A static foam generating apparatus comprising:

a pope having an inner diameter of about 1 inch to about 3 inches (about 2.5 cm to about 7.6 cm), an axis, an input end, and an output end;

a plurality of perforated discs disposed in the pipe axis; and

a plurality of spacer rings disposed in the pipe, a spacer ring separating each perforated disc from each adjacent perforated disc.

2. The apparatus of claim **1**, wherein the pipe has an inner diameter of about 2 inches (about 5.1 cm).

3. A static foam generating apparatus comprising:

a pipe having an inner diameter, an axis, an input end, and an output end;

a plurality of perforated discs disposed in the pipe, the discs positioned parallel to each other and perpendicular to the pipe axis, wherein each disc has a thickness of about 0.19 inches (about 0.48 cm); and

a plurality of spacer rings disposed in the pipe, a spacer ring separating each perforated disc from each adjacent perforated disc.

4. A static foam generating apparatus comprising:

a pipe having an inner diameter, an axis, an input end, and an output end;

a plurality of perforated discs disposed in the pipe, the discs positioned parallel to each other and perpendicular to the pipe axis; and

a plurality of spacer rings disposed in the pipe, a spacer ring separating each perforated disc from each adjacent perforated disc, wherein each spacer ring has a thickness of about 0.25 inch to about 1.25 inches (about 0.64 cm to about 3.2 cm).

5. The apparatus of claim **4**, wherein each spacer ring has a thickness of about 0.75 inch (about 1.9 cm).

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,422,734 B1
DATED : July 23, 2002
INVENTOR(S) : Sethuraman et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 6,
Line 5, change "pope" to -- pipe --.
Line 8, after "pipe" and before "axis" insert -- , the discs positioned parallel to each other and perpendicular to the pipe --.

Signed and Sealed this

Twenty-sixth Day of November, 2002

Attest:

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

Attesting Officer